Concentrated Solar Power Techno-Economic Feasibility Study

Thomas Courte, Ryan Jung, Kyle Lam, Amanda Quinn, Riley Snider
Schulich School of Engineering, University of Calgary

ABSTRACT

This research project provides SolarSteam, with a techno-economic feasibility study for capacity building and system integration in multiple industries.

The project includes a technical analysis for describing and illustrating the application of SolarSteam's enclosed concentrated solar technology integrated with various industries that use low to medium heat in their production processes along with a detailed investigation of heat transfer fluids and materials of the vacuum tube and parabolic trough.

ABOUT SOLARSTEAM

Purpose Statement: SolarSteam's purpose is to decarbonize some of the highest emitting and hardest to abate heavy industry segments.

Description of Technology: SolarSteam's system uses solar collectors to concentrate sunlight in order to generate hot water and steam. A transparent membrane enclosure increases efficiency by keeping the collectors clean and reduces capital cost by allowing for lightweight materials that don't require rigid foundations and expensive controls.

SolarSteam's generators will operate in conjunction with existing boilers and use boiler feed water to provide direct hot water and steam generation. SolarSteam systems reduce cost up to 40% by displacing fossil fuels and GHGs by up to 50% compared to conventional powered heat generation.

CONTACT

Thomas Courte
Energy Engineering Student

Email: thomas.courte@ucalgary.ca
Phone: 403.993.9736

Robert Garth
Director of Technology - SolarSteam

Email: robert@solarsteam.ca
Phone: 403.397.0616

Website: https://solarsteam.ca

INTRODUCTION

The concentrating solar power (CSP) industry continues to emerge and evolve within the global energy industry and supply chains. CSP technologies use an array of lightweight solar curved (trough) mirrors to reflect and concentrate sunlight onto a receiver. The concentrated sunlight is used to directly heat pressurized water in the receiver to produce steam or hot water that can be utilized for industrial purposes.

Most of the learning and experience within the CSP industry has remained internal to specific companies attributable to commercial interests and unproven ideas on the improvement of operations. A significant setback inhibiting the deployment of CSP's is the lack of knowledge regarding the technologies viability within various industries production processes. Evaluating the economic performance of industrial processes prior to project implementation is vital as it helps assess the economic viability of a process and provides direction to research, development, investment, and policy making.

The primary objective is to complete a techno-economic feasibility study for capacity buildings and system integration in multiple industries. The project will include a technical analysis for describing and illustrating the application of CSP technology integrated with various industries that use low to medium heat in their production processes.

METHODS

The aim of the project is to consider the method and design of system integration into various industries with associated analysis of process parameters and variables, heat requirements, solar heat generation, capacity, etc.

The techno-economic feasibility study covers system integration into the following industries:

1. Beverage industry (brewery)
2. District heating and cooling
3. Petrochemical

RESULTS & DISCUSSION

SolarSteam's technology is specifically designed to operate in extreme climates therefore, the teams analysis focused on industry applications within the harsh/variable climate of Alberta.

Key Takeaway: The average natural gas price in 2021 for Alberta was \$3.37/GJ (\$12.13/MWh). This is significantly lower than the average electricity pool price in Alberta for 2021 (\$102/MWh). This significantly effects the economics for solar thermal in Alberta because you are offsetting a lower energy cost for heating than you are for electricity.

Capital subsidy supports a wide range of projects that are well-aligned with growth priorities and emission reduction targets. It is important to leverage government funding to increase project economics (i.e., payout, internal rate of return, undiscounted revenue, etc.). Capital subsidy typically can be stacked up to 75% of project costs however, 25% and 50% capital subsidy is most widely seen in industry.

A parametric analysis was completed for both ground mounted and rooftop applications. SolarSteam's unit cost was utilized for each application and economics were run based on no subsidy, 25% subsidy, and 50% capital subsidy for chosen sizes completed in the parametric analysis.

It was determined that payout significantly decreases with the utilization of capital subsidy however, due to the low energy cost offset payout is still longer than expected.

Capital efficiencies also occur when you more modules. The manufacturer can provide a reduction in the \$/module which also helps economics.

Heat transfer fluid analysis to determine the best fluid based on thermal conductivity, heat transfer coefficient, Nusselt Number, friction factor and Reynolds Number. Water, nitrate salt, and liquid sodium were analyzed and water was determined to be the most feasible heat transfer fluid.

Heat transfer analysis was also conducted on the parabolic trough and vacuum tube. Different materials and three gasses were analyzed. It was determined that the amount of energy produced is directly proportional to the working temperature fluid, therefore the best combination of material and gas does not provide significantly more energy than the worst combination. Therefore, it is recommended to use materials with the lowest cost to reduce production cost of the absorber.